Department of Civil Engineering

EFFECTS OF NON-MOTORIZED VEHICLES ON MIXED TRAFFIC IN INDIA

A thesis submitted in partial fulfillment of the requirement for the degree of

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Rourkela

Certificate

This is to certify that the thesis entitled, "**Effects of non-motorized vehicles on mixed traffic in India**" submitted by **Tanzim Hussain** in partial fulfillment for the prerequisites for the degree of Bachelor of Technology, 2014-15 in Civil Engineering at National Institute of Technology, Rourkela is a bona-fide work completed by him under my overseeing and guidance.

To the utmost extent of my knowledge, the matter incorporated in this report has not been submitted to any other University/Institute for the conferral of any certificate.

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Abstract

Heterogeneous traffic composed of both motorized and non-motorized vehicles are a common feature of urban Indian roads. In India there are no lane segregation of non-motorized vehicles and motorized vehicles, therefore the theoretical models fail to analyze the situation completely. This research mainly analyzes the impact of non-motorized traffic on overall performance of traffic parameters.

An effort is made to scrutinize effects on capacity due to variation of share of non-motorized vehicles and a significant drop in capacity due to increment of non-motorized traffic is observed. The investigation also reveals shifting of lateral distribution of non-motorized vehicles from curb side towards the center on increment of share of non-motorized vehicles. Another observation is made on the impact of distance headway on velocity in roads carrying both way traffic. Dependence of speed on distance headway of motorized vehicles is observed to be much higher than non-motorized vehicles.

The results clearly shows the negative impacts of non-motorized vehicles on capacity of roads and average velocity of traffic flow. Further decrement in segregation due to changes in lateral distribution of non-motorized vehicles decreases the qualitative aspect of performance of motorized vehicles and contribute towards increment in road accidents.

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Chapter 1 Introduction

Non-motorized vehicles are an indispensable part of the transportation system of India, it serves as the main source of transportation for a majority of the Indian population. The underprivileged section of the society is completely dependent on non-motorized transportation, particularly in rural areas where non-motorized vehicles dominates both the passenger and goods segment. In urban areas non-motorized vehicles are directly linked to the public transportation systems, they play the role of end transportation network for the poorer section. Non-motorized vehicles may contribute as high as 80% of the traffic flow in rural areas, whereas in cities its maximum contribution may reach 50-60% of the total traffic flow.

The traffic flow patterns in urban India is quite different from that of western cities, western cities have homogeneous traffic due to presence of separate lanes for buses and non-motorized vehicles. In India, traffic is heterogeneous i.e. it comprises of both motorized and non-motorized vehicles, again there are no clear demarcation of lanes and traffic regulations for segregation of vehicles. Non-motorized vehicles have a profound impact on the basic traffic parameters in India, particularly due to their lower speed compared to motorized vehicles.

The share of walk trips and bicycle trips are decreasing in urban areas, however the absolute number of bicycles and rickshaws are actually increasing even in the major cities such as Delhi and Mumbai. As non-motorized vehicles serve as the only means of transportation for a large underprivileged section of the Indian population, these are sure to increase with the expansion of Indian cities for the next few decades.

Non-motorized vehicles are responsible for decreasing the capacity of lanes. In multilane roads non-motorized vehicles generally occupy the outermost or curb-side lanes, however in intersections and bus stops non-motorized vehicles get mixed with the motorized vehicles. That's why effects of non-motorized vehicles such as increment in accidents and decrement in capacity are more evident in intersections.

In this paper attempts are made to analyze the influence of non-motorized vehicles on capacity, lateral density distribution and velocity of entire traffic flow.

1A Traffic Parameters

Speed (u)

Speed is the distance travelled per unit time, for the purpose traffic flow study average speed of vehicles for a particular time duration in a particular road segment is generally considered. Generally time mean speed and space mean speed are used for calculation of speed; time mean speed is the average speed of vehicles at a particular point of the highway during a certain time interval whereas space mean speed is defined as the ratio of length of particular section of highway and the average time required by vehicles crossing that particular section.

Flow (q)

The total number of vehicles passing a particular point of the highway in a certain time interval is defined as flow. It reflects the number of vehicles that the highway can handle. Mathematically is has a unit of vehicles per unit time.

$q=n/t$ n: number of vehicles, t: time interval

Density (k)

Density is the total number of vehicles in a particular length of the highway at an instant of time. It reflects the level of congestion in the road segment. Generally density is averaged for a duration of time for experimental observation. Mathematically is has a unit of vehicles per unit length of lane.

$k=n/x$ n: number of vehicles, x: length of road segment

Time Headway (TH)

Time headway is the time difference to reach a certain point between corresponding points of successive vehicles in a stream traffic flow. Mathematically it is the multiplicative inverse of flow.

$TH=1/q$

Distance Headway (DH)

In a stream traffic flow, distance between corresponding points of successive vehicles is termed as distance headway. Mathematically it is the multiplicative inverse of density.

$DH=1/k$

1B Graphical Relations

Space-Time Relation

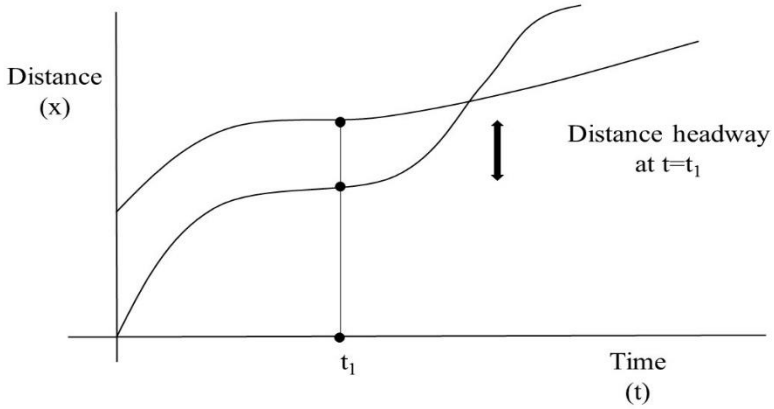

Figure 1.1 Space Time Diagram

It is the most basic curve that represents the location of vehicles along a road according to time. The slope of the curve at an instant of time gives the speed whereas the vertical distance between two curves at a particular time gives the distance headway at that time.

Flow-Density Relation

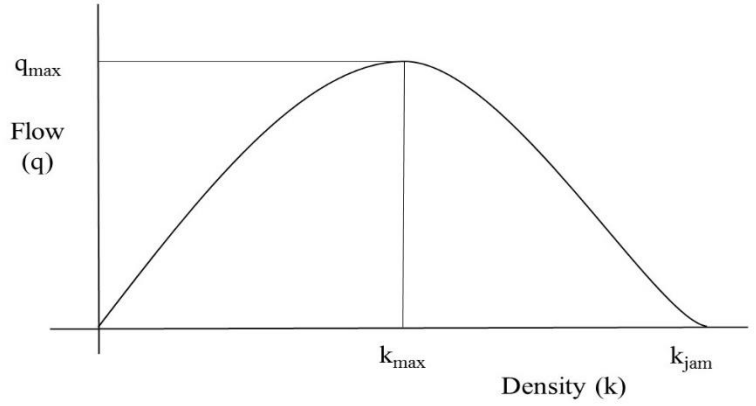

Figure 1.2 Flow Density Diagram

Generally, flow increases with density until a certain point and then decreases. The slope of a line connecting the origin to a point on the curve gives the speed for that density and flow. The maximum possible flow is known as the capacity of the road.

Speed-Density Relation

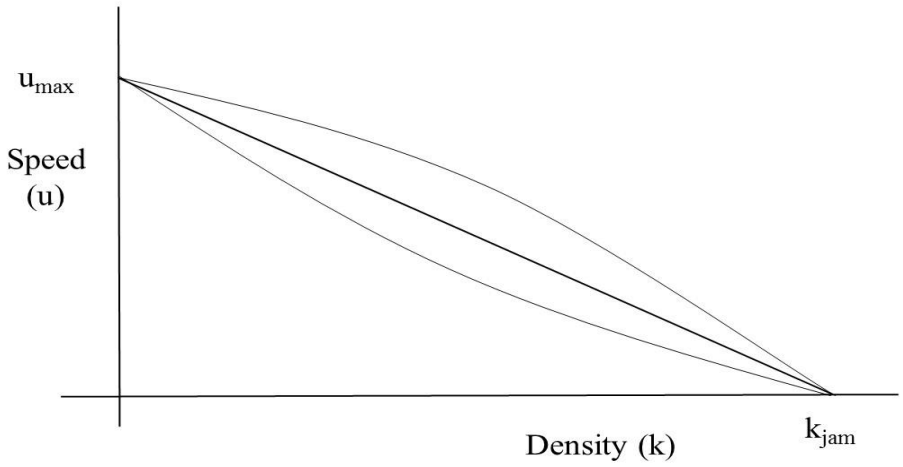

Figure 1.3 Speed Density Diagram

Speed decreases as the density increases; speed is maximum at zero density and zero speed in observed in jam condition. Experimental observations show that the curve is close to linearity.

Speed-Flow Relation

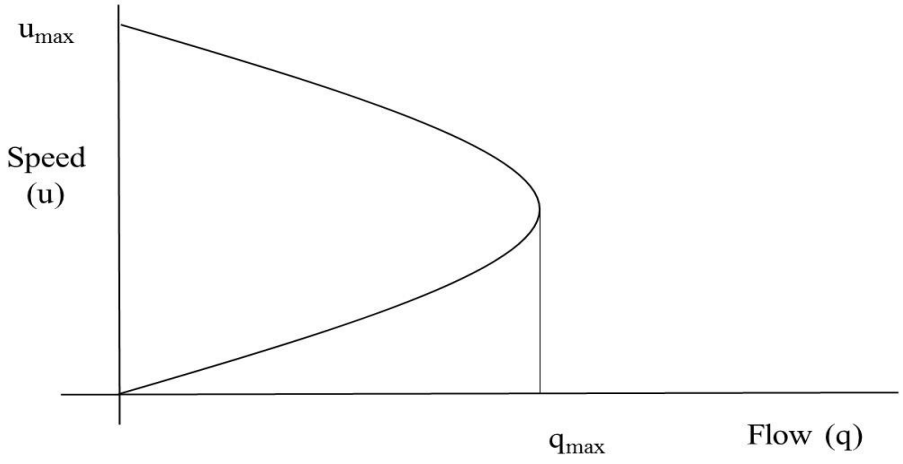

Figure 1.4 Speed Flow Diagram

When flow is zero speed can be zero as there are no vehicles on the road, else a maximum speed is observed in the free road. All values of flow except the maximum flow yields two speed.

1C Passenger Car Unit

Passenger Car Unit (PCU) is the impact that a mode of transportation has on traffic parameters compared to a single car. It may be defined as measure of the relative space requirement of a vehicle class compared to that of passenger car under a specified set of roadway, traffic and other conditions. PCU specifications for various vehicles according to IRC 64:1990 are listed in the following table.

Vehicle	**PCU**	**Type**
Motorized two wheeler	0.5	Motorized
Passenger car, Pick up van, Auto rickshaw	1.0	Motorized
Light Commercial Vehicle, Agricultural tractors	1.5	Motorized
Truck, Bus	3.0	Motorized
Tractor Trailer	4.5	Motorized
Cycle	0.5	Non-motorized
Cycle Rickshaw	2	Non-motorized
Hand cart	3	Non-motorized
Tonga	4	Non-motorized
Bullock cart	8	Non-motorized

Table 1.1 PCU specifications listed by IRC 64:1990

Chapter 2 Objective

The research is mainly concerned with the analysis of impact of non-motorized vehicles in traffic flow characteristics under Indian situations.

The three main categories addressed in this research paper are listed below:

- Capacity analysis
- Lateral density distribution analysis
- Speed & distance headway relations

Capacity analysis is related evaluation of capacity and study of flow-density curves in various locations. Efforts are made to study the changes observed in capacity due to variation in share of non-motorized vehicles in overall density.

Lateral flow distribution analysis deals with study of distribution of non-motorized vehicle flow laterally across the road from the left end to the right in various locations. Changes in distribution pattern with respect to variation in share of non-motorized vehicles in overall density are studied.

Finally, speed versus distance headway curves for various locations are studied. Relation of velocity with the distance headway of motorized and non-motorized traffic in both way traffic are analyzed.

Chapter 3 Literature Review

A number of studies are conducted all over the world on the impact of non-motorized vehicles in overall traffic flow. A huge percentage of those studies are concentrated in Asian countries where the traffic conditions are somewhat similar to India. Some the studies are discussed as follows:

Tiwari (1999) scrutinize the level of segregation of motorized and non-motorized traffic in Delhi, India; both in single lane and multilane roads. The investigation revealed that bus stops force the non-motorized vehicles towards the center of road thereby decreasing lateral segregation with motorized vehicles and increasing accidents. Again study on separate lanes for buses and cycles unveils the importance of cycle lanes for the successful use of bus lanes.

Oketch (2003) studied the variation in traffic parameters due to introduction of non-conventional vehicles such as bicycles & motorcycles on conventional traffic flow composed of private cars, buses & trucks. The investigation found that the heterogeneous streams had reduced lane saturation flows in comparison to homogeneous conventional streams, although the trends weren't always consistent. It is also observed that heterogeneous flows have peculiar features that resulted in highly scattered plots of flow, speed & density.

Rahman et al (2003) analyzed effects of non-motorized vehicles on urban traffic characteristics in Bangladesh. They observed that non-motorized vehicles had a negative impact in the basic traffic parameters of speed, flow & density. A linear relationship was found between overtaking volume and total volume; however no clear pattern was observed on the impact of non-motorized vehicles on overtaking volume.

Rahman and Nakamura (2005) concentrated on overtaking movements with respect to total traffic volume for undivided urban streets along with the repercussions of variation in percentage of rickshaw. They additionally attempted to classify level of service of heterogeneous traffic into four categories from free flow condition to congested flow condition. Total number of overtaking per unit length & speed of passenger cars are considered as working parameters for level of service.

Tiwari et al (2007) analyzed the difference between homogeneous traffic flows with strict lane discipline in Western countries and heterogeneous traffic flows found in Indian cities. Basic traffic

parameters & curves are studied by classifying the vehicles into: motorized four wheelers, motorized three wheelers, motorized two wheelers & non-motorized vehicles. They presented a methodology to verify the continuity equation as well as modifications in passenger car units to better understand the traffic flows under Indian conditions.

Pan and Kerali (2007) studied the relation between non-motorized traffic flow and speed of motorized vehicles on various traffic conditions. A linear relationship is observed between the speeds of motorized vehicles and non-motorized traffic flow volumes. A model was finally calibrated to evaluate speed of motorized vehicles under congested conditions and varying non-motorized flow volumes.

Oketch (2007) studies heterogeneous traffic characteristics in Kenya and developed a model based on fuzzy logic rules. The model takes into account the overtaking of motorized vehicles by two-wheeled vehicles in congested regions with almost no movement of motorized vehicles. The effects of partial use of two lanes simultaneously and change of lanes gradually are also analyzed in the model.

Xiao et al (2011) studies capacity and flow characteristics of under mixed traffic conditions in China. The impact of pedestrian and non-motorized vehicle movement on capacity near intersections were analyzed and an exponentially decrease in capacity is observed on increment of pedestrian and non-motorized vehicle movement.

Chapter 4 Data Collection & Extraction

Videos of various locations in Rourkela are used to extract basic data values manually into the form of Microsoft Excel sheets.

4A Location

Videos are collected in 4 locations in Rourkela.

- Aambagaan
- Rourkela Main Market
- Birsa Chowk
- Konark Cinema Hall

Location	Section Width (m)	Section Length (m)	Traffic Type
Aambagaan	9	5	Two-way
Main Market	7	5	Two-way
Konark Cinema Hall	7.5	5	One-way
Birsa Chowk	10	7	One-way

Table 4.1 Details of data collection locations

Video length: 30 minutes

Secondary videos are used.

4B Extraction Methodology

- Videos are played in Daum Pot Player, screen markers are used to demarcate the boundaries of the required section.
- A screen marker line is drawn perpendicular to the road from one end of the road to another. The number of vehicles passing the line per minute is evaluated to obtain the flow. Similarly, flow for non-motorized vehicles and motorized vehicles are evaluated separately.
- Number of vehicles present in the road section are observed at intervals of 10 seconds; these are averaged for per minute to obtain the density. Similarly density for non-motorized vehicles and motorized vehicles are evaluated separately.
- Speed data for non-motorized vehicles, motorized vehicles and total vehicles are obtained by dividing respective flow with respective density.
- Screen markers are used to divide the road width into 7 strips, density data for each strip are obtained for non-motorized vehicles, motorized vehicles and total vehicles.

The extracted data are:

- Flow
    - Non-motorized Vehicle Flow
    - Motorized Vehicle Flow
    - Total Flow
- Density
    - Non-motorized Vehicle Density
    - Motorized Vehicle Density
    - Total Density
- Speed
    - Non-motorized Vehicle Speed
    - Motorized Vehicle Speed
    - Total Speed
- Density for individual strips
    - Non-motorized Vehicle Density
    - Motorized Vehicle Density
    - Total Density

Chapter 5 Results & Data Analysis

5A Capacity Analysis

The flow-density relations are analyzed and capacity for all locations are evaluated as well as compared with the percentage share of non-motorized vehicles in total density.

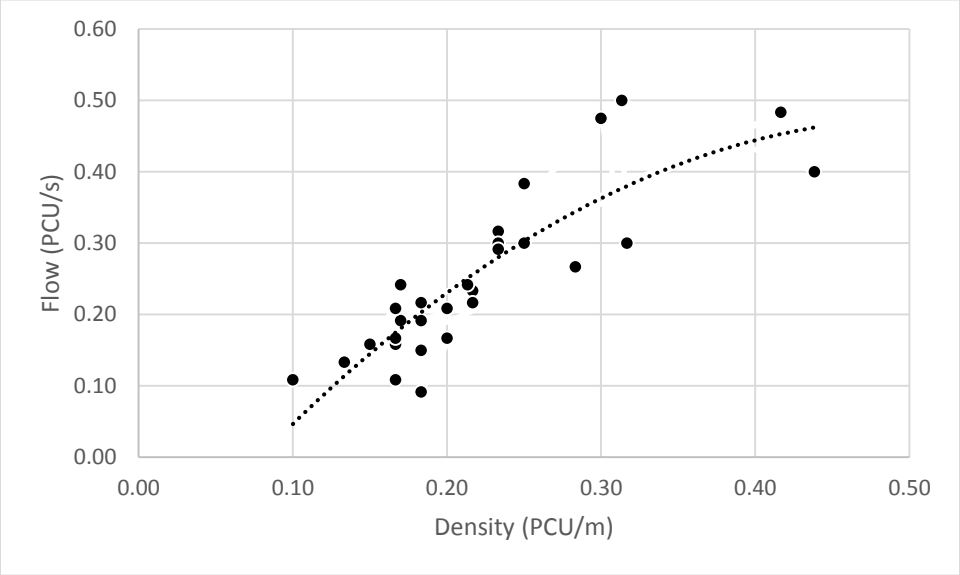

Figure 5.1 Flow-Density Curve for Downstream flow in Aambagaan

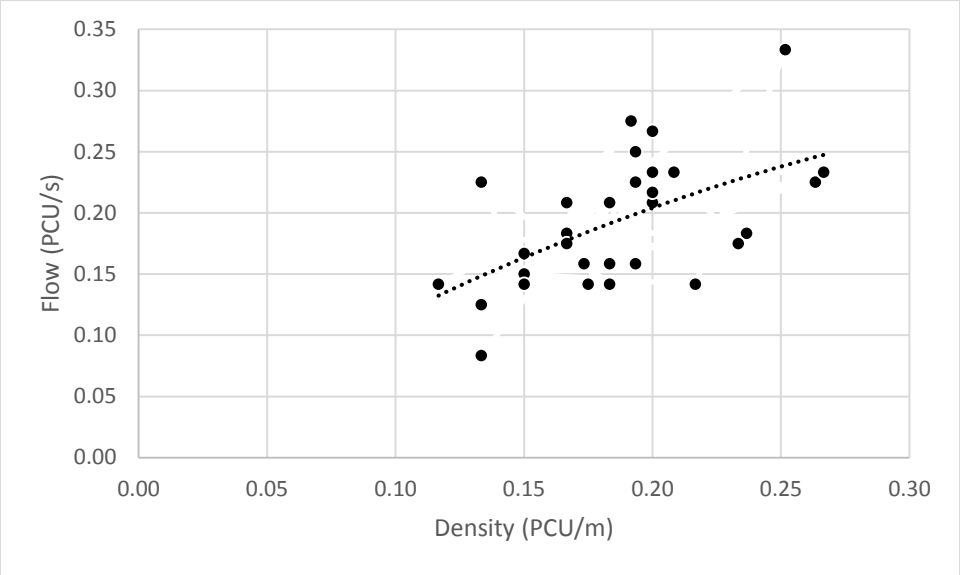

Figure 5.2 Flow-Density Curve for Upstream flow in Aambagaan

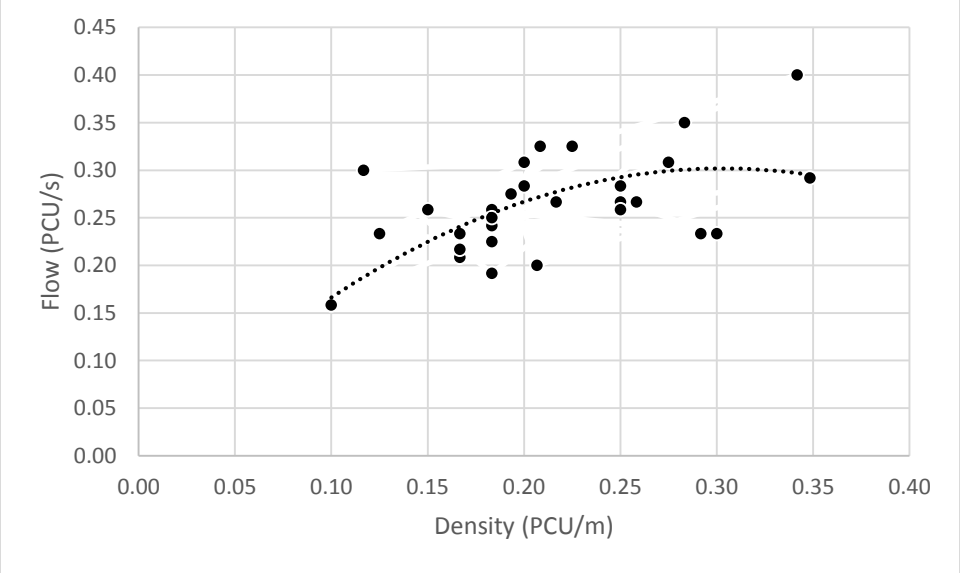

Figure 5.3 Flow-Density Curve for Downstream flow in Main Market

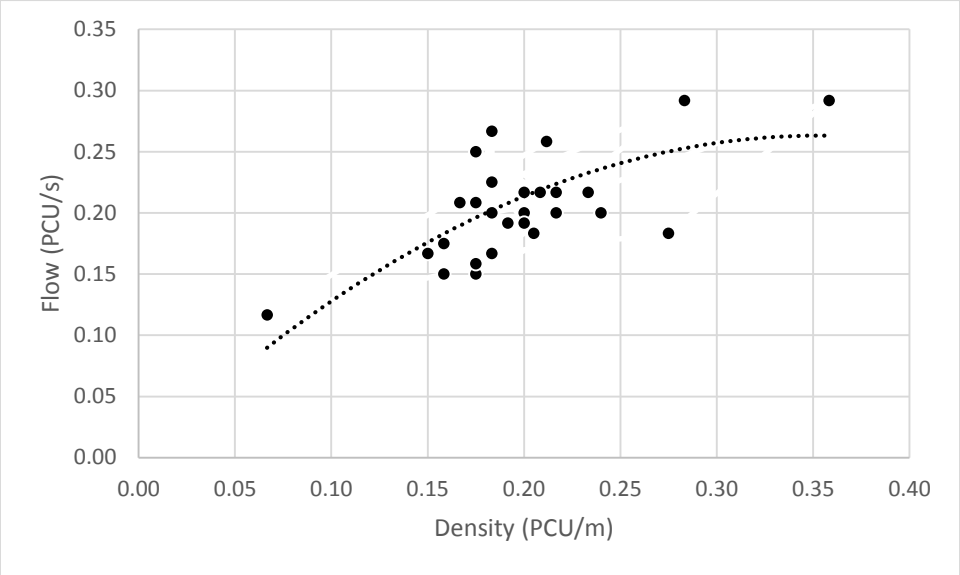

Figure 5.4 Flow-Density Curve for Upstream flow in Main Market

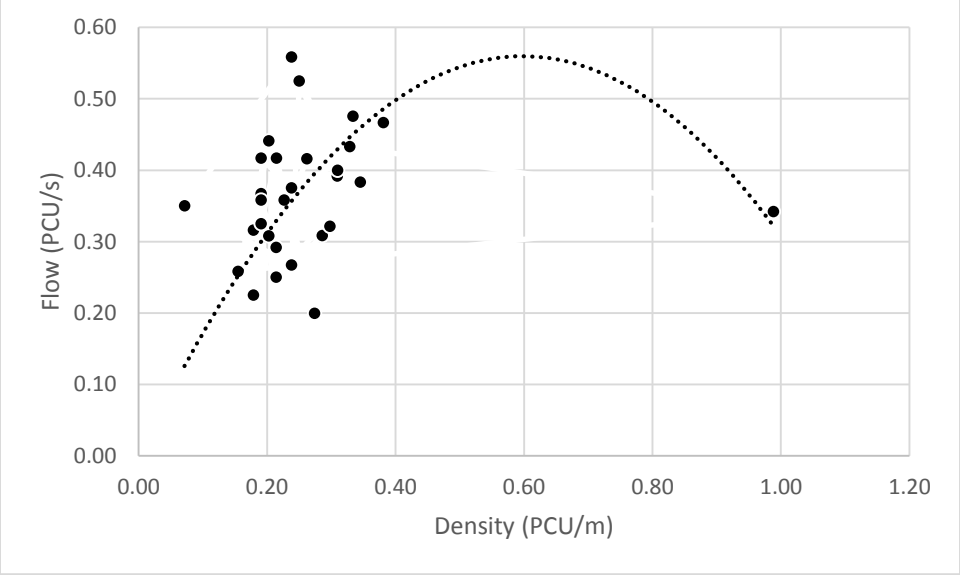

Figure 5.5 Flow-Density Curve for Birsa Chowk

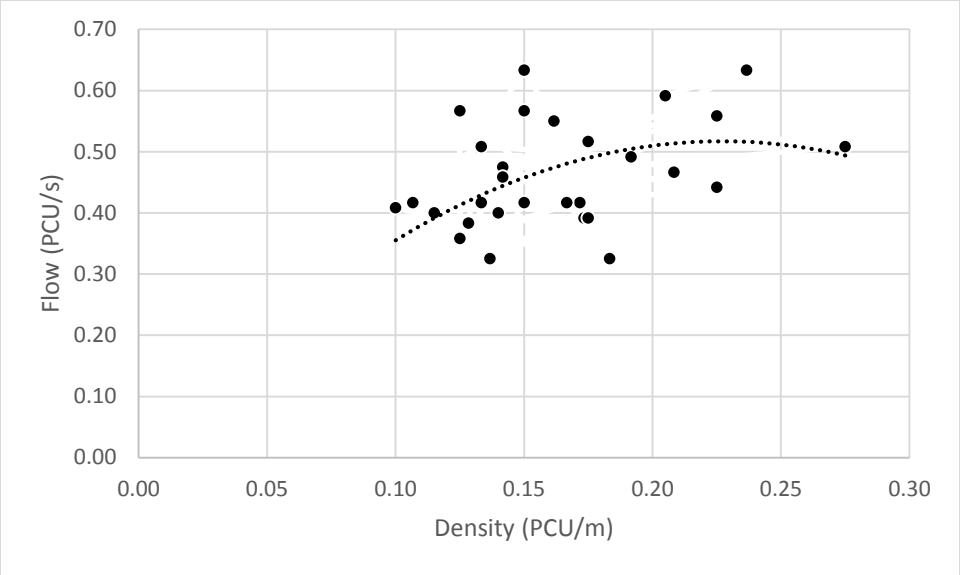

Figure 5.6 Flow-Density Curve for Konark Cinema Hall

The capacity values obtained from the curves are adjusted for to represent capacity of a single lane for forward moving traffic.

$$\textbf{Adjusted Capacity} = \textbf{Capacity} * \frac{\textbf{3.5}}{(\textbf{Road width}) * (\textbf{Traffic Type})}$$

Location	Adjusted Capacity (PCU/s)	% contribution of NMV in density
Aambagaan Downstream	0.10	46.67
Aambagaan Upstream	0.13	25.83
Birsa Chowk	0.21	21.00
Konark Cinema Hall	0.19	29.64
Main Market Downstream	0.08	44.99
Main Market Upstream	0.07	63.78

Table 5.1 Variation of Adjusted Capacity and Percentage Contribution of NMV in Density

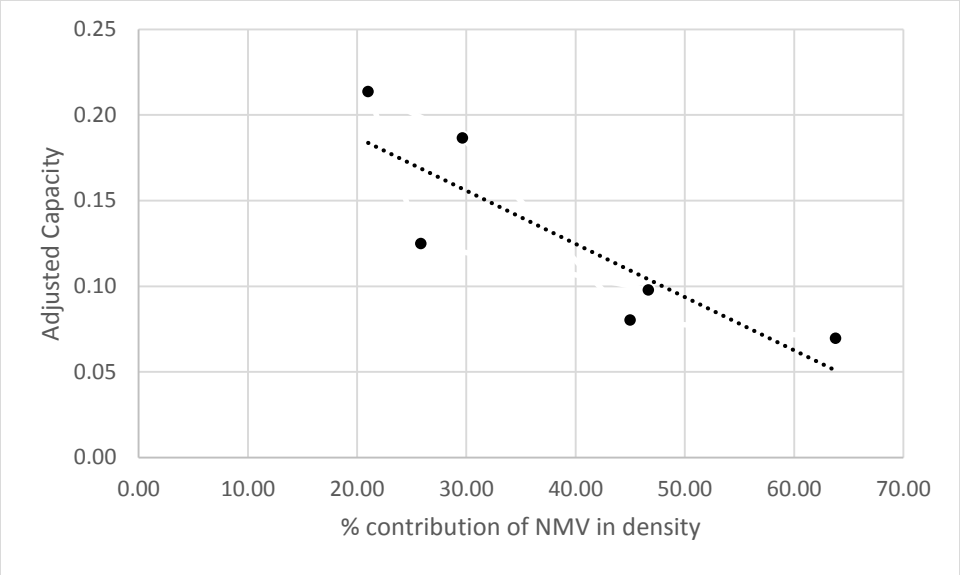

Figure 5.7 Adjusted Capacity-Percentage Contribution of NMV in Density

From the above trend line it is clearly observed that increment in share of non-motorized vehicles density linearly decreases the capacity.

5B Lateral Density Distribution

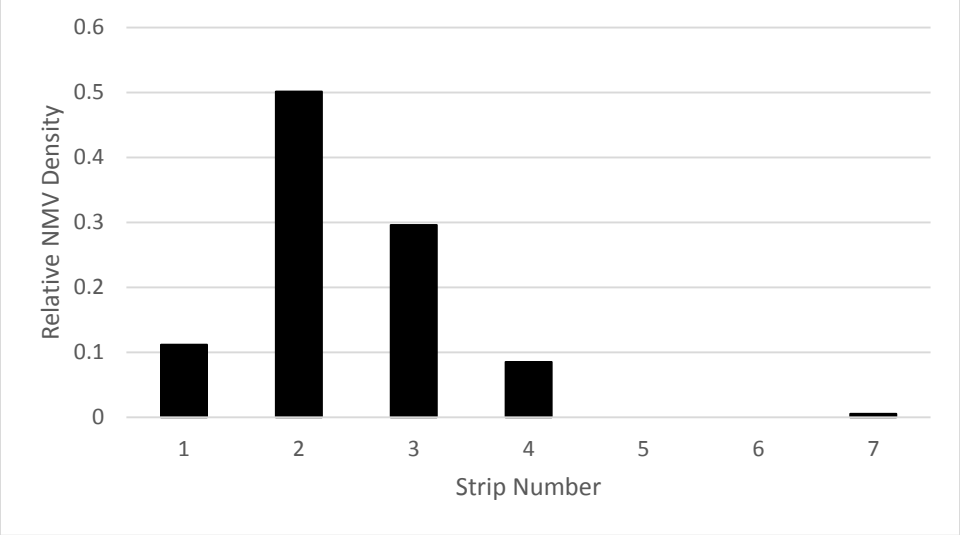

Figure 5.8 Lateral Density Distribution of NMV for Downstream Flow in Aambagaan

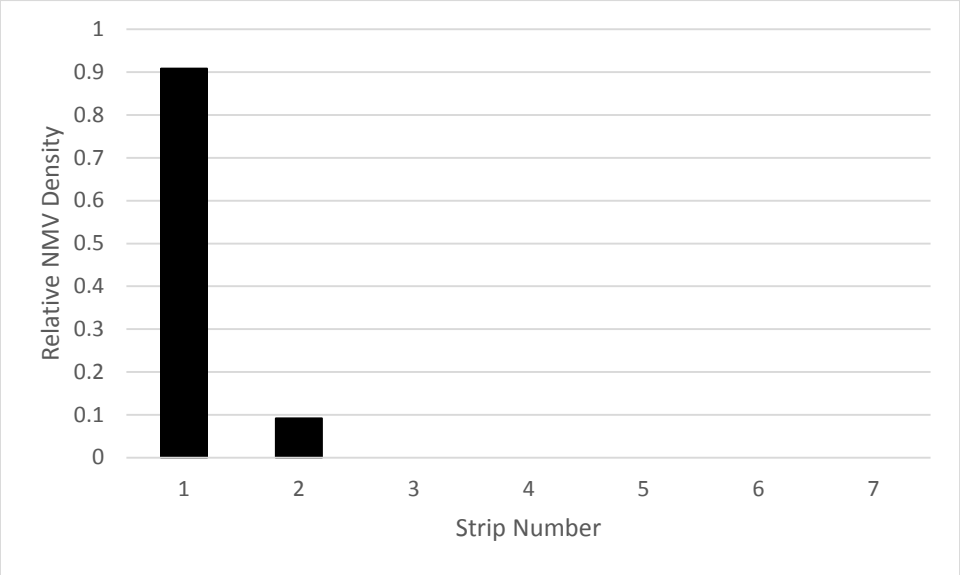

Figure 5.9 Lateral Density Distribution of NMV for Upstream Flow in Aambagaan

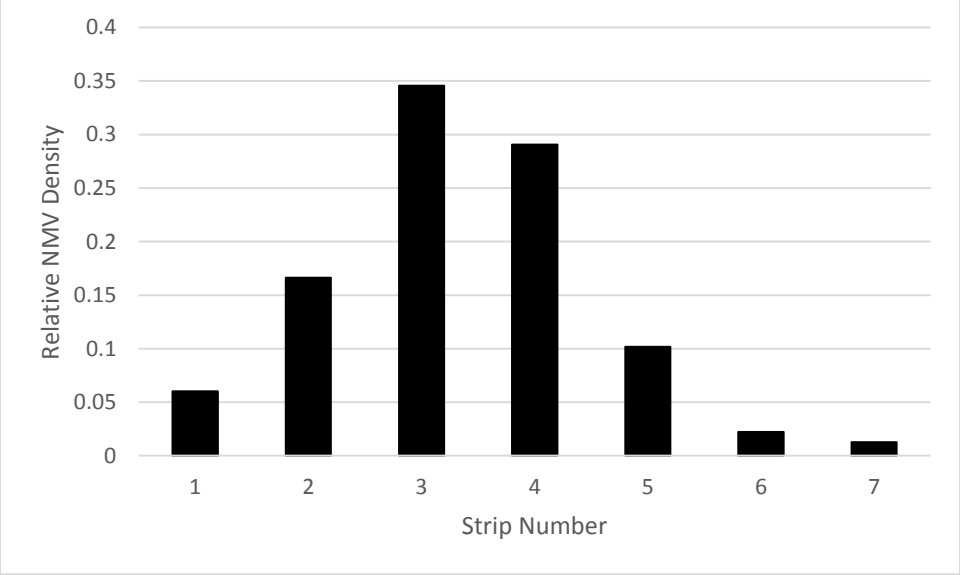

Figure 5.10 Lateral Density Distribution of NMV for Konark Cinema Hall

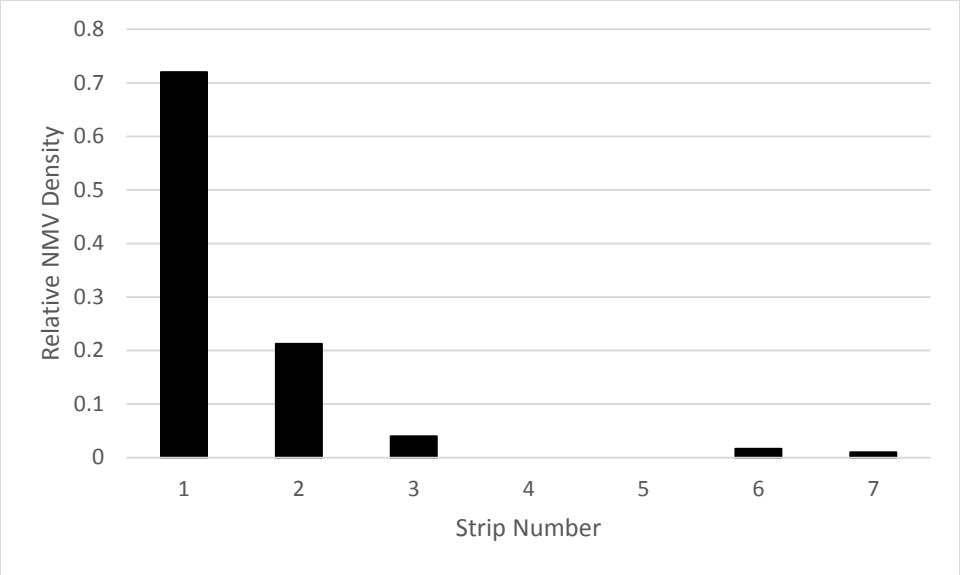

Figure 5.11 Lateral Density Distribution of NMV for Downstream Flow in Main Market

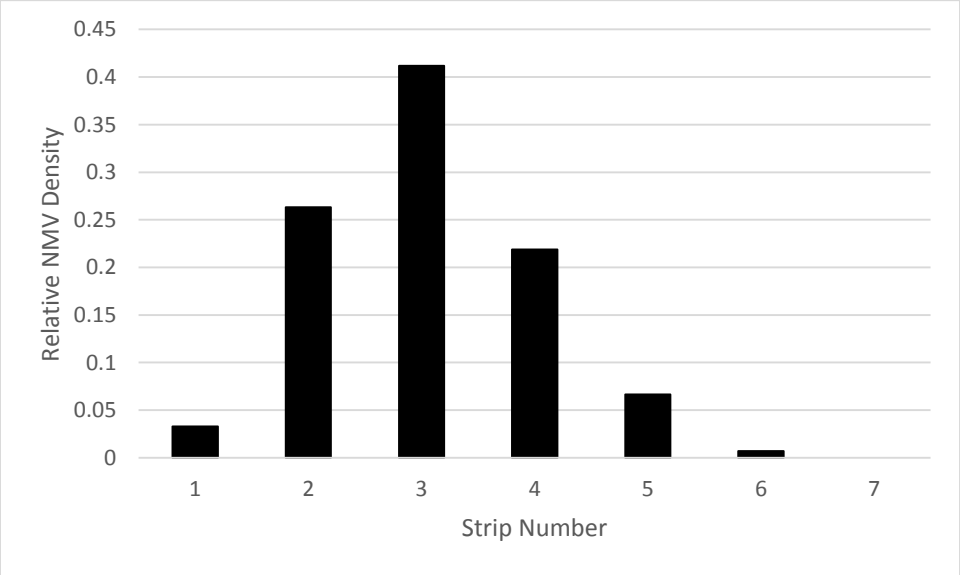

Figure 5.12 Lateral Density Distribution of NMV for Upstream Flow in Main Market

The center of area under lateral density distribution of non-motorized vehicles curves are obtained and its horizontal distance from the left side of the road are evaluated.

Location	Road Width (m)	Distance of center from left end of road (m)	Percentage distance of center from left end of road (m)	Percentage contribution of NMV in density
Aambagaan Downstream	9	3.06	34.02	46.67
Aambagaan Upstream	9	1.40	15.60	25.83
Main Market Downstream	7	1.03	20.53	44.99
Main Market Upstream	7	2.17	43.49	63.78
Konark Cinema Hall	15	3.56	23.76	29.68

Table 5.2 Distance of center of density of NMV from left end of road

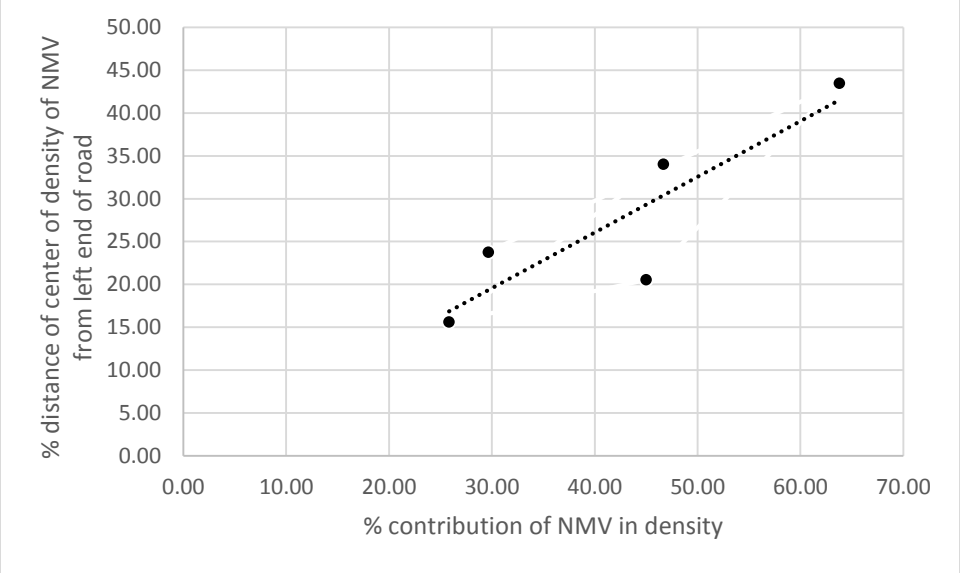

Figure 5.13 Variation in percentage distance of center of density of NMV with percentage contribution of NMV in density

From the above trend line it is observed that non-motorized vehicles tend to occupy the left side of the road, however increment in non-motorized vehicles force them towards the center.

5C Speed & Distance Headway Relations

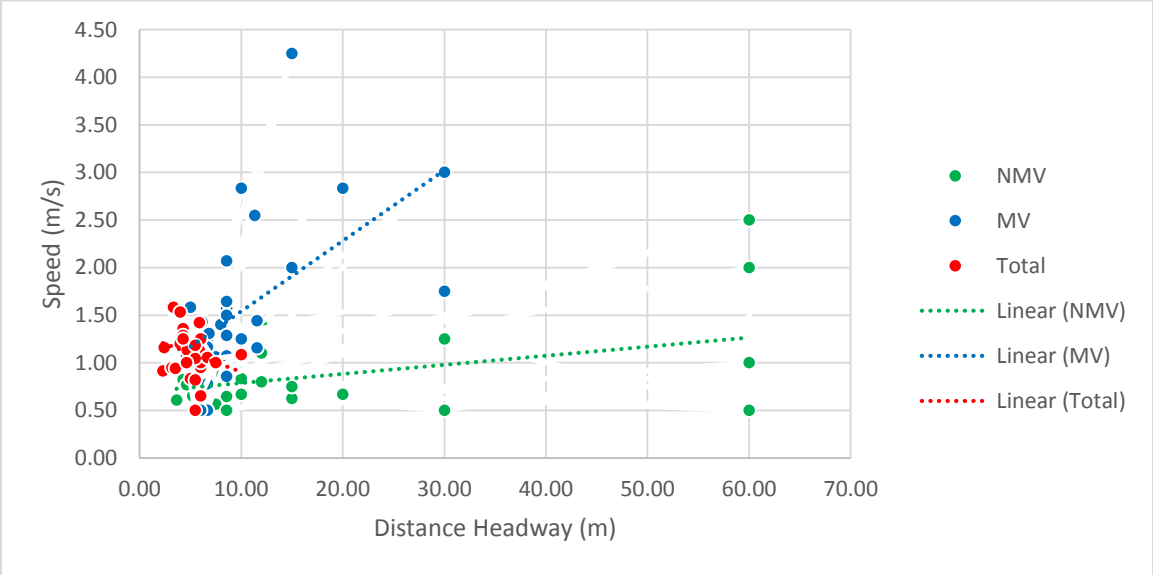

Figure 5.14 Speed-Distance Headway Curve for Downstream flow in Aambagaan

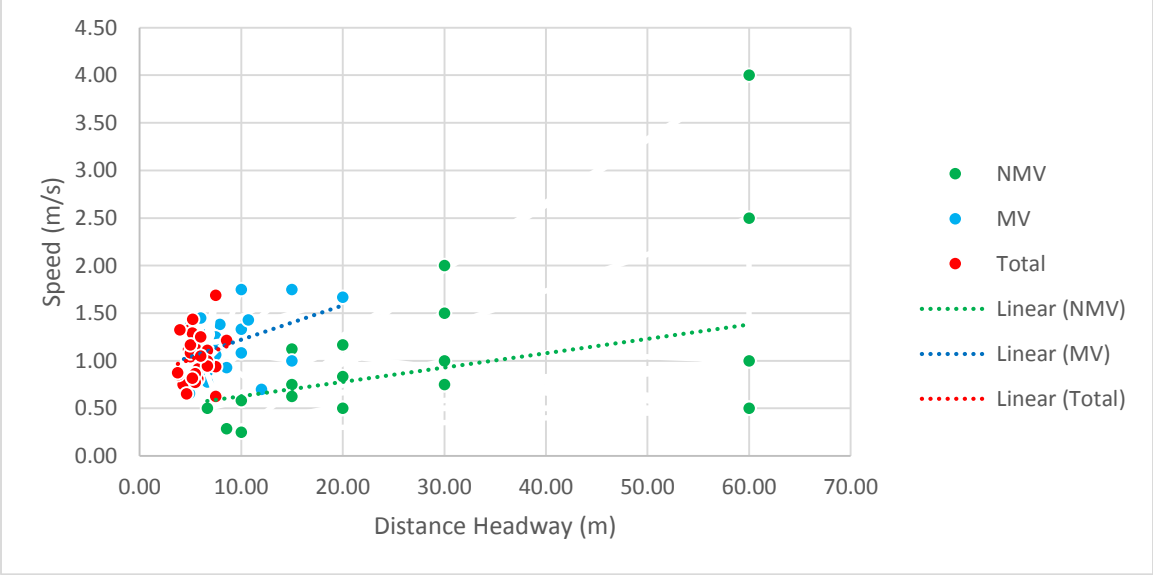

Figure 5.15 Speed-Distance Headway Curve for Upstream flow in Aambagaan

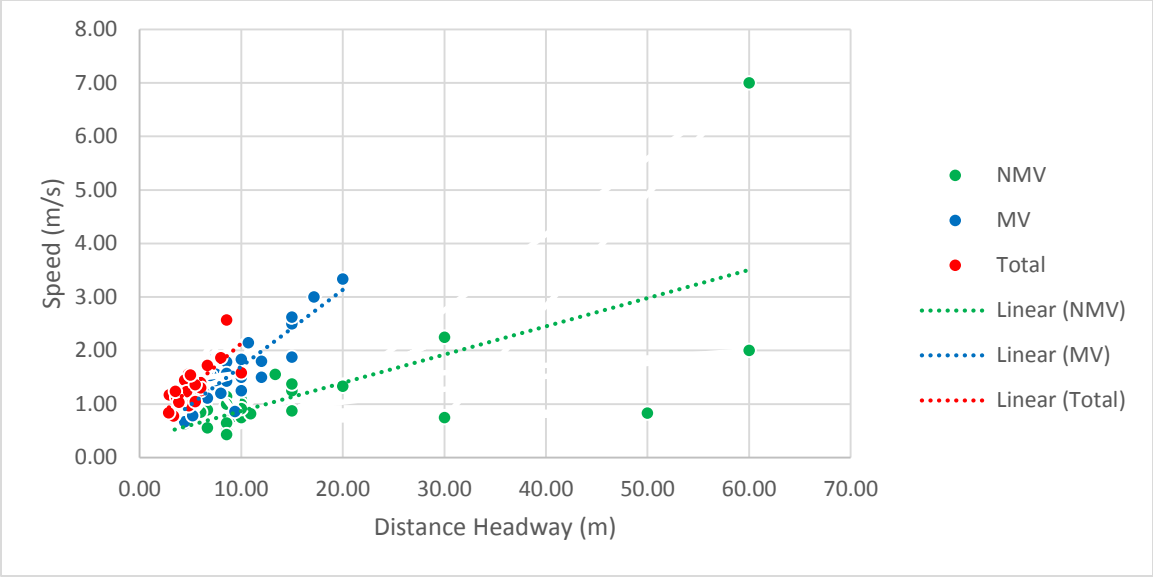

Figure 5.16 Speed-Distance Headway Curve for Downstream flow in Main Market

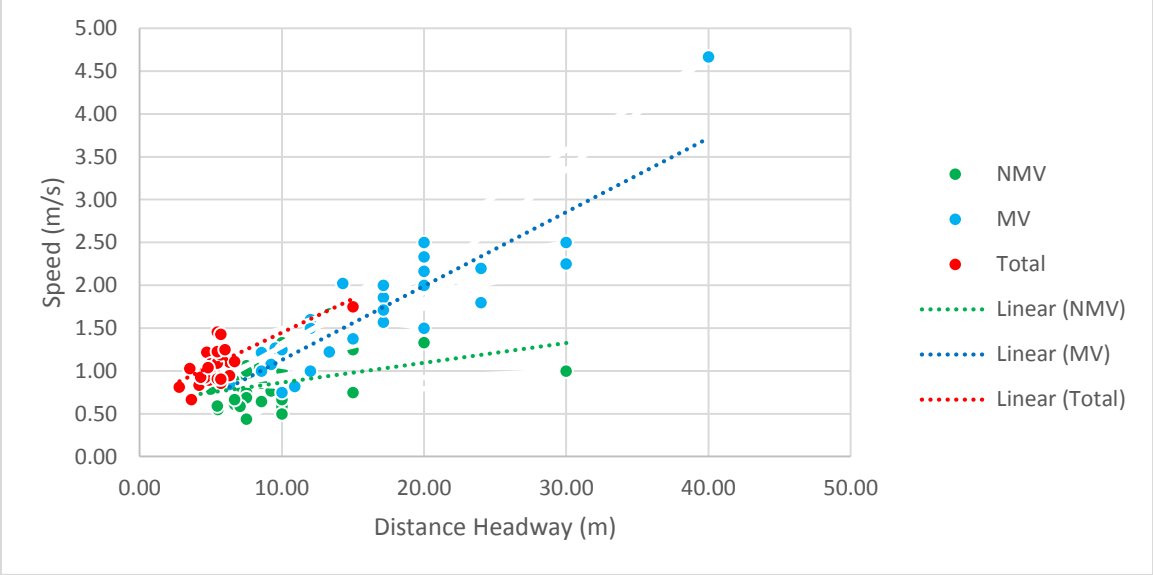

Figure 5.17 Speed-Distance Headway Curve for Upstream flow in Main Market

A linear relationship is observed between speed and distance headway, however a lot of scattering is observed due to effect of non-motorized vehicles and improper lane changing in both way traffic.

Now speed is linearly related to distance headway of motorized and non-motorized vehicles in both forward and backward moving traffic.

$$V = C_0+C_1D_1+C_2D_2+C_3D_3+C_4D_4$$

where

V is speed

D_1 is distance headway of non-motorized traffic in forward direction

D_2 is distance headway of motorized traffic in forward direction

D_3 is distance headway of non-motorized traffic in backward direction

D_4 is distance headway of motorized traffic in backward direction

C_0, C_1, C_2, C_3, C_4 are constants

Regression technique are used to obtain the value of all constants for downstream and upstream traffic flows in Aambagaan and Main Market. The justification of the constant values may be provided by comparison of original velocities and velocities evaluated from distance headway by use of the constants.

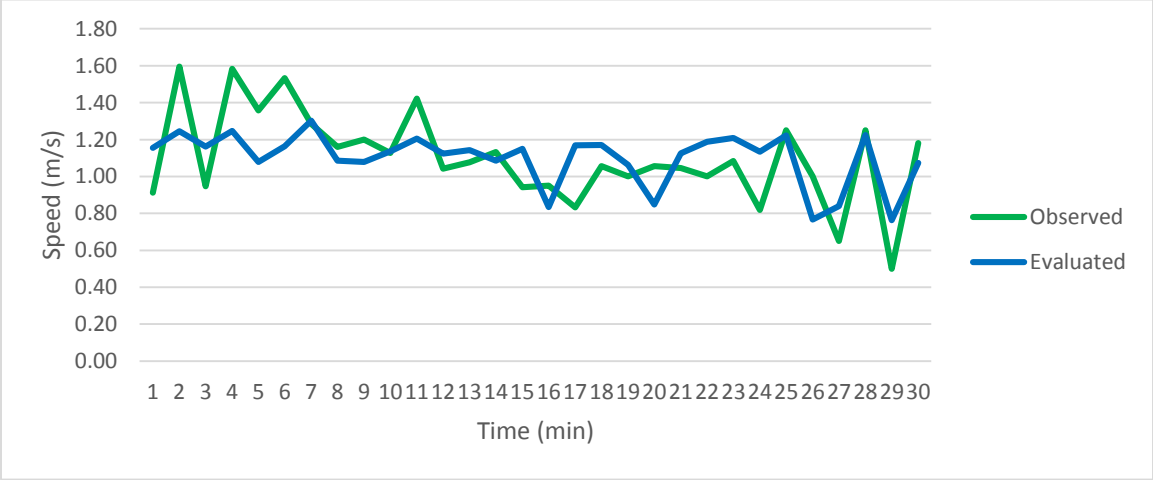

Figure 5.18 Observed & Evaluated speed for downstream flow in Aambagaan

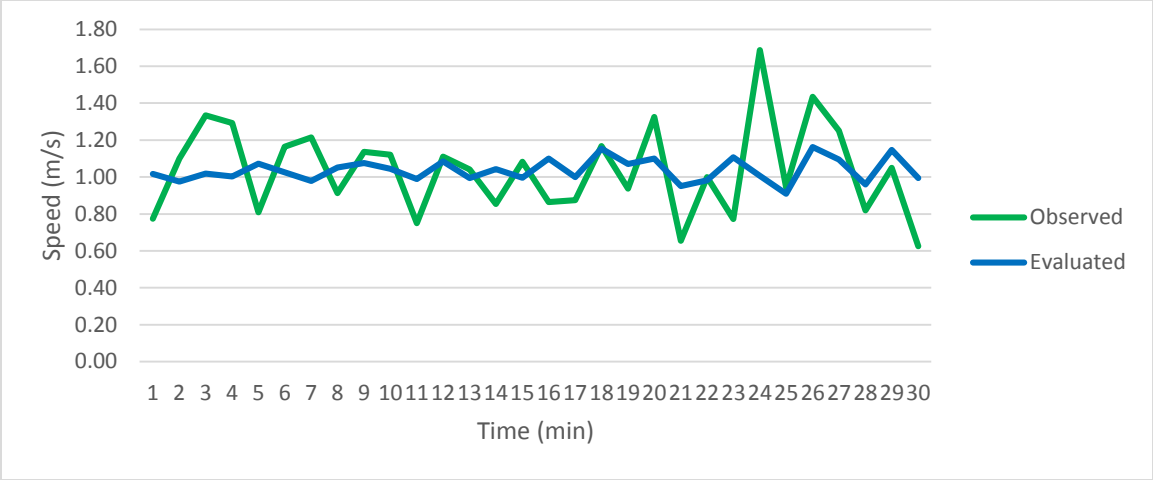

Figure 5.19 Observed & Evaluated speed for upstream flow in Aambagaan

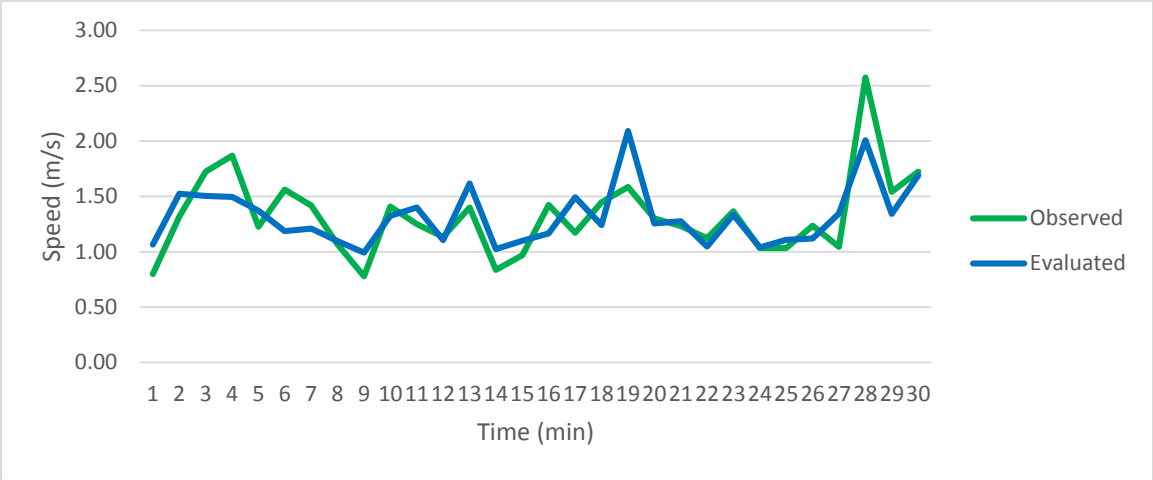

Figure 5.20 Observed & Evaluated speed for downstream flow in Main Market

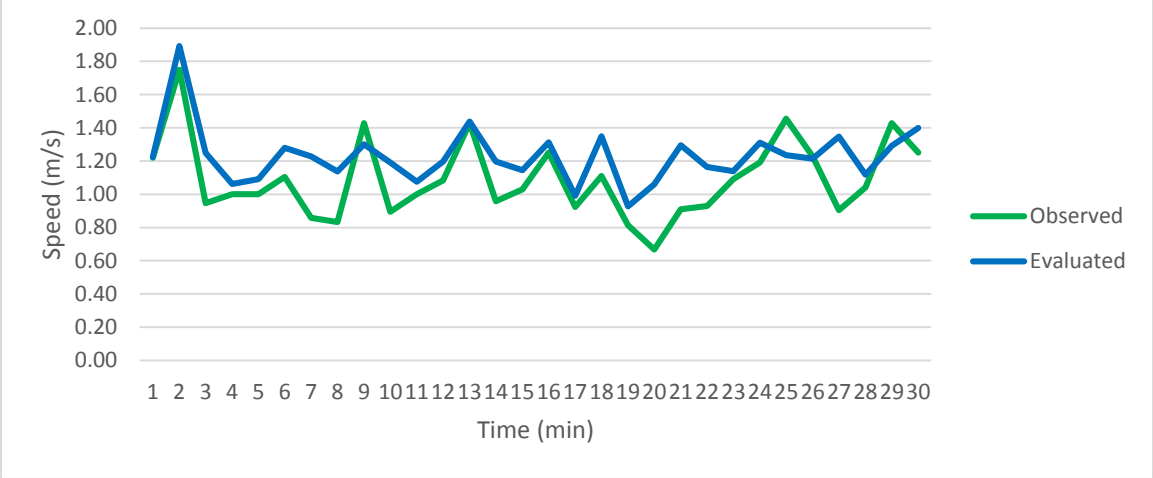

Figure 5.21 Observed & Evaluated speed for upstream flow in Main Market

The constants obtained are as follows:

Location	C_0	C_1	C_2	C_3	C_4
Aambagaan Downstream	1.1816	-0.0060	0.0046	-0.0023	0.0072
Aambagaan Upstyream	0.9766	0.0016	-0.0074	0.0017	0.0036
Main Market Downstream	0.5896	0.0167	0.0367	0.0156	-0.0033
Main Market Upstream	0.8387	0.0245	0.0109	-0.0009	-0.0155

Table 5.3 Values of Constants

The magnitude of the constants reveals the influence of respective distance headways on speed.

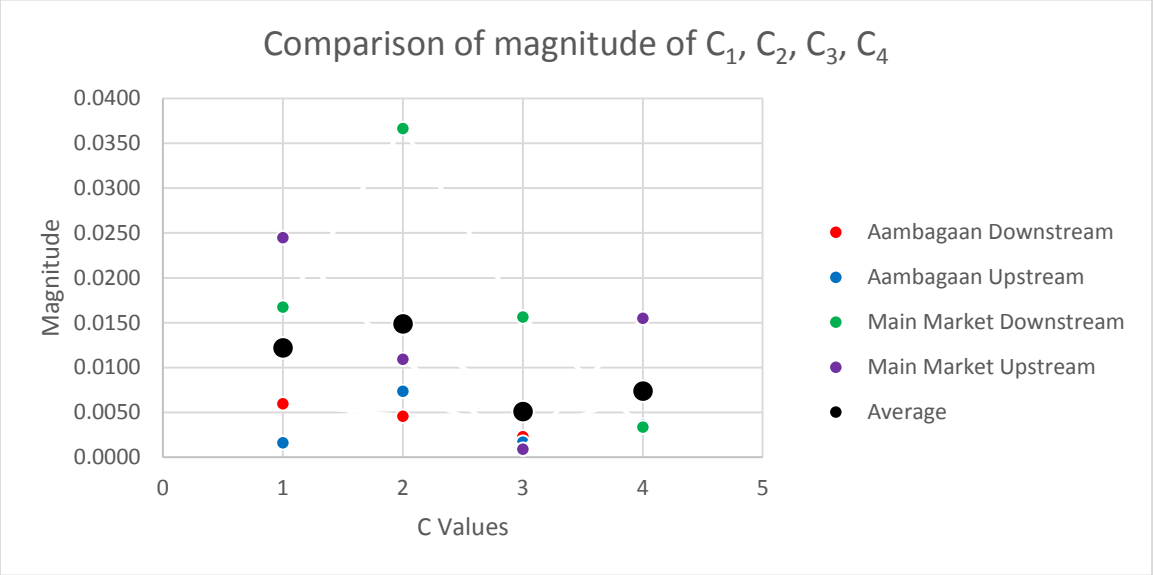

Figure 5.22 Comparison of magnitude of constants

From the average values in the above plot it can be concluded that distance headway of motorized vehicles has more impact on velocity than distance headway of non-motorized vehicles. Again, the distance headway of backward traffic has far less impact on velocity then distance headway of forward traffic.

Chapter 6 Conclusion

Observations and analysis of the traffic data in this research implies a number of conclusions.

The negative effects of non-motorized vehicles on capacity are clearly observed, a linear decrement of capacity is observed on increasing the share of non-motorized vehicle density.

Significant relations are observed between the lateral distribution of non-motorized vehicles and percentage contribution of non-motorized vehicles on density. The center of the lateral distribution of non-motorized vehicles move linearly towards the center from the curb side with respect to increment of non-motorized traffic.

Linear relations are observed between velocity and distance headway, however significant scattering of data points are observed. Velocity in roads allowing two-way traffic are related to the distance headway of motorized and non-motorized vehicles both in forward and backward traffic flow. Analysis reveals that distance headway of motorized traffic have more effect on velocity compared to distance headway of non-motorized vehicles. Another observation shows distance headway of forward traffic have far greater impact on velocity than distance headway of backward moving traffic

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